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Sustainability at home: Policy measures for energy-efficient appliances

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ABSTRACT

Residential energy consumption is now an important component of total energy consumption and its related emissions. In addition, this consumption has significant potential for growth in both developed and developing countries, as average incomes increase, and domestic appliance numbers rise. Reduction in this energy use may be achieved both through conservation measures, and through increased efficiency in its use. This paper focuses on energy efficiency in appliances—those many devices through which household energy is consumed. The policy instruments available to promote the uptake of more efficient devices, and issues associated with their use, are reviewed, drawing on developed country experiences to date. The instruments available are more limited than in other energy applications, and largely comprise information dissemination, forms of subsidy, and regulation. The last is commonly used in the form of minimum energy performance standards. Assessment of the three instrument types and issues with their use suggests that regulation is the most important measure—albeit with several qualifications on the manner of its use.

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1. Introduction

In global efforts to reduce greenhouse emissions much attention has properly been given to large emission sources such as energy-intensive industry. Other sectors however are of similar importance in emission terms. In particular, emissions from

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residential energy consumption can be of the same order as those from industry [1]. Residential energy use is important both for its present size and potential growth, and for the fact that it impacts directly on individuals in their daily lives. It is this energy consumption, and the ways through which it may be reduced, which are the focus of this paper.

The means of addressing residential energy emissions – the policy instruments – are necessarily different to those important in other sectors. The objectives of this paper are to identify the scale and composition of residential energy consumption, assess the policy instruments available to address it and their relative effectiveness, and suggest ways in which they may be best used. It uses as its basis developed country experiences to date, given both the association of appliance use with income, and the greater availability of appliance types in developed markets. Discussion is centred around the role of appliances in domestic energy use. For convenience, the term 'appliance' is used here to describe all those numerous devices, large and small, through which energy is consumed in the production of various services to households.

Reduction in consumption by such equipment may be driven by both *efficiency* improvements and *conservation* measures, the latter implying a lesser use of the service in question. Besides implying different actions the two approaches differ in the policy measures which are relevant. The focus here is on securing improvements in efficiency and the ways by which that may be achieved. The discussion considers particularly the role of regulation (in the form of minimum energy performance standards (MEPS)) as an active policy instrument.

2. The importance of appliance energy use

Addressing appliance energy consumption is important both because of its present consumption and emissions, and also for its likely growth. Household energy consumption (effectively representing appliance use in the most general sense) represents a significant portion of total energy consumption in developed countries. Importantly, as the major energy carrier is electricity with its associated emissions, households are a major greenhouse gas (GHG) source. Domestic consumption's share of national electricity consumption is of the same order as, and in some cases higher than, that of industry [2]—the more common target for greenhouse emission reduction initiatives. Residential energy end-use emissions (that is, the total emissions arising from the use of domestic appliances) in the EU27 countries in 2009 comprised 25% of total emissions—virtually the same as industry at 26% [1]. Table 1 shows electricity consumption data for a range of OECD countries of different economic 'size' and income, the EU27, and a world average.

The table shows the significant share of total electricity consumption going to domestic use, and the varying ratio between residential and industrial electricity use. It shows also the markedly varying electricity use per capita, and GDP per capita as a proxy for average income levels. The latter is notable for the evident disparity between average world income, and that of the OECD countries shown. That has important connotations for the potential growth of domestic energy consumption, as discussed below.

The scale of residential consumption implies that it must be addressed as a part of any effective overall energy/emissions policy. Appliance ownership is increasing in higher-income countries [4], particularly in consumer electronics and computing-related equipment. In addition, given the association of appliance ownership with income, GDP per capita increases in most developing countries will lead to further major growth in appliance utilisation—a point well highlighted by the difference between the OECD country incomes shown above, and world average income. The scale of that potential growth is evident from examples such as China (of similar population to the OECD [3])—whose electricity consumption per capita is currently less than 30% of the OECD average [5]. The US Energy Information Administration predicts that by 2015 non-OECD country residential energy use will exceed that of OECD countries [66]. Failure to deploy effective policy instruments will lead to significant emission increases from these sources.

In terms of the contribution of the various appliance types, it is difficult to develop detailed comparative data because of differences in the categories and definitions used by countries reporting data. Illustrative data for five countries and the EU-27 are given below in Fig. 1.

Several issues are evident from Fig. 1. First, the data depict substantial differences in category energy consumption between the countries listed. These differences are a product of

- variation in national energy supply mix (e.g., New Zealand, unusually for a developed country, derives 38% of domestic heating from woody biomass [12])
- differences in national per capita energy consumption, and electrical energy consumption, as noted in Table 1
- real differences in the relative use of individual appliance classes and, not least
- likely definitional and methodological differences in category data reporting.

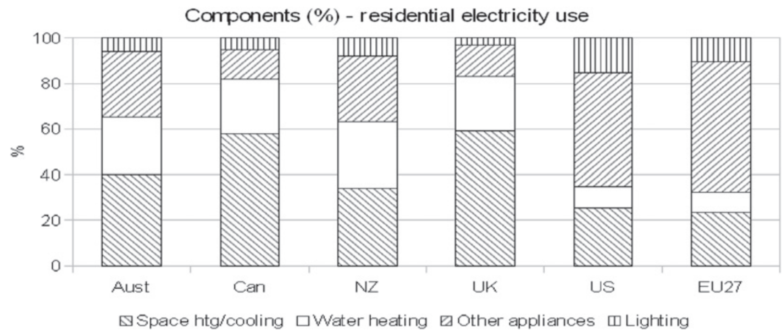
The differences in results between countries is worthy of study in its own right but is not developed further here, being noted primarily to indicate the range of potential consumption associated with the major appliance classes.

Second, it is apparent that appliances fall into two groups—those few 'thermal' appliances of high power consumption (space heating and cooling, water heating and possibly refrigerator/freezers), and a larger number of appliances of individually smaller consumption. The latter are numerous and increasing (in Australia for example from 52 per residence in 2000 to 67 in 2005 [4]), and the two groups quite different in nature. Appliance purchasing decisions are likely to be made on different bases for the two groups, and this has implications for the policy instruments with which to address them, as discussed below.

An increasingly important category of consumption not separately noted above but which is embedded in many devices is that of 'standby' consumption, the electricity consumption due to appliances in their idle state—that is, when they are not delivering the service for which they were designed. The consumption level is

Table 1
Residential electricity consumption and income.

	Aust	Canada	NZ	UK	US	EU27	World
Residential use as % total	23	26	28	29	31	24	27
Residential as % of industry	61	85	87	104	151	71	66
Residential use, MW h/capita/yr	2.77	4.84	2.98	1.93	4.54	1.64	2.48
GDP/cap (2009)	$39,900	$38,100	$27,300	$34,200	$46,000	$31,900	$11,100



Data for	Australia	Canada	NZ	UK	US	EU27
Year/source	2006-7 / [6]	2004 / [7]	2005 / [8]	2005 / [9]	2008 / [10]	2007 / [11]

Fig. 1. Components of residential electricity use (% of total) in selected countries. See [6–11].

typically low, but highly variable both between and within appliance types. Measured average standby power data for European devices showed CRT monitors, for example, to have nearly three times the standby power of LCD monitors. As importantly, the ratio between the average standby power and that from the best available technology (BAT) was around 5:1 for LCD monitors, and 10:1 for CRT monitors. While standby levels are relatively low (around 3 W and 6 W for the two monitor types), the total number of devices concerned is high and hence total consumption is also high. The IEA compared standby power consumption survey data between Japan and Australia in 2005. Australia (which, as Table 1 shows, is not at the upper end of the household electricity consumption range) with an average of 67 appliances per house, recorded average standby consumption of 807 kW h per year, or 10.7% of total household consumption. Japan, with fewer appliances per house (28) recorded standby consumption of 308 kW h per year, or some 7.3% of total household consumption [4]. In the US, with over 40 appliances per household, it was suggested that standby power could actually account for the majority of electricity consumed by some devices such as set-top boxes, audio equipment and video equipment [67].

Within the overall set of appliances is one set of devices which well represent the difficulties of dealing with high-number, small consumption devices. These are the ubiquitous external power supply packs for devices of all types from mobile phones to laptop computers. In the 2009 US Residential Energy Consumption Survey, for example, nearly a third of households had at least four devices such as mobile phones plugged in and charging at home [66]. There are believed to be some 5.5 billion of these devices in use in the world, consuming some 50 TW h per year, or around 1–1.5% of total residential electricity [4]. They are clearly a significant source of energy use which must be addressed, but – as with standby power – by means different to those of larger appliances.

In summary, residential electricity use is significant in terms of national total consumption, and is highly dispersed—both over millions of individual households and within those, over a range of appliance types with significantly differing consumption levels. It is not surprising therefore that addressing such consumption in policy terms has its own particular difficulties. Before considering that however it is useful to look briefly at the broad range of policy instruments available for related purposes, using the wider field of overall GHG emission reduction as an illustration.

3. Policy instruments

Policy instruments are the tools that governments use to implement their policy objectives. Available policy instruments vary widely in nature, and selection of the most appropriate instrument is a key factor in the achievement of those objectives—an aspect as true in the climate policy area as any other. This is demonstrated by a broad literature in climate policy addressing instrument selection in diverse circumstances—for example in the promotion of wind power [13], supporting waste wood utilisation [14], and the selection of instruments to suit market segments [15], among many others. The diversity of applications makes climate change and energy policy a fruitful field for such study. This paper contributes to that by considering the very specific use of energy in domestic consumption, and the policy instruments most suited to reducing that consumption and its resultant emissions.

In the broader field of energy/emission reduction there exists a wide range of instruments by which government may pursue their policy targets. That however is not the case here. For a number of reasons discussed below, the range of policy instruments which may be put to use in this area is notably more limited than elsewhere, and that in turn has implications for how the available instruments should be used. The objective here is to assess the policy instruments associated with addressing such emission sources, their likely effectiveness, and what specific issues need to be addressed to ensure that effectiveness. The following discussion briefly examines the range of policy instruments available and in use in the broad field of emission reduction. The instruments from that set which are relevant to appliance energy are then identified, together with the factors influencing their effectiveness in that application.

4. Policy instruments for climate change

The International Energy Agency [16], in its broad 'Policies and Measures' overview of member countries, identified instruments in use for emission reduction as generally falling into five types—three 'policy families', and two specific tools:

1. policy processes (strategic planning, disseminating information, and consultation)
2. fiscal instruments (incentives—tax/subsidy measures))
3. regulatory instruments
4. voluntary agreements and
5. tradeable permit systems.

Here, 'policy processes' are treated as being represented by information programs, as the active form of intervention in that group. In addition to the basic instrument types, some practical instruments may combine elements to form hybrid instruments. Examples of individual instrument types, and certain issues with their use, are briefly reviewed below.

4.1. Information programs

These initiatives seek to address one possible cause of market failure—a lack of information on the part of market participants, which prevents them from taking what should be rational economic decisions ('rational' being used here in the specific economic sense of the "reasoned pursuit of self interest" [17]). For example, producers may be unaware of potentially profitable means of reducing their energy consumption, or consumers unaware of the costs in operation of motor vehicles with differing fuel efficiency. Providing information may enable both to identify means by which they may reduce energy consumption, and gain economically. The UK Carbon Trust for example, like many such national agencies, works with industry through their Industrial Energy Efficiency Accelerator program, included in which is the provision of 'best practice' case studies in various industries [18]. At the individual consumer level, the Australian Government has since 2002 required new vehicle labeling showing fuel consumption and greenhouse emission rates, to facilitate car buyers making informed choices in their vehicle purchase [19]. For appliances, labeling is the most common information approach.

Issues impacting on the effectiveness of information measures include the actual magnitude of the energy consumption being addressed, the nature of consumer response, and the 'principal-agent problem'.

4.1.1. Energy consumption

As noted above, appliances may be broadly divided into a few large energy consumers, and numerous smaller devices. With the former, the lifecycle energy operating cost may well be such as to allow an economic case to be made for energy efficient devices, providing that prospective purchasers may be so persuaded. Even where that is not the case, energy may well be a sufficient part of lifecycle cost that it is included in overall appliance assessment. That is not so with all appliances. Even amongst the larger of these, energy costs are not high. The author's own relatively recent washing machine and refrigerator for example would, under the specified operating cycles, consume around $A70 and $A98 per year in electricity costs respectively, using Australian Government label data and January 2011 NSW electricity prices [20]. A 10% difference in those costs (as might for example arise through comparison between alternative brands) would therefore lead to cost impacts of around sixteen and nineteen *cents* per week, an amount most unlikely to materially affect consumer behaviour. In marketers' terms, the amount is unlikely to exceed the "just noticeable difference" between alternatives, and hence unlikely to influence consumer response [21]. As a purchasing decision determinant, energy consumption is even less significant when considered in the context of other performance parameters. Particularly in the computer and consumer electronics sector, the purchase decision is more likely to be driven by aspects such as screen size and resolution, processor speed, or any of the myriad performance variables through which suppliers seek to differentiate their products. That suggests that the value to be gained from labelling systems may be very limited if the information being presented is not among the principal selection criteria.

Consumer response: appliance labeling is premised on the assumption that making adequate information available to consumers should result in rational decisions in favour of more efficient appliances, where appropriate. This is however difficult to objectively establish. In its 2005 review of energy efficiency programs, the Australian Productivity Commission concluded "Appliance energy-performance labels have some influence on consumers *after they have short-listed products on the basis of characteristics such as price, performance, capacity and style*" [22] (emphasis added). Tversky [23] described a very similar process in his 'elimination by aspects' (EBA) model, an approach which might be used by consumers as an heuristic aid to simplifying decision-making in a situation of product selection. As noted in Section 4.1.1, such a process could well eliminate energy efficiency as a factor in selection unless it were considered to be a primary selection variable.

In another observation, in the UK in 2006 following a detailed survey (including interviews with over one thousand consumers) Oxera (consulting for DEFRA) concluded "The most important finding is that future energy savings do not appear to be an important factor in a householder's decision…to buy efficient appliances…. If the energy savings are considered as part of the decision at all, they feature only weakly" [24]. Were that to be the case generally, the value of labelling as a policy instrument in its own right would appear limited. Considered in association with Section 4.1.1 above, it might be expected that this problem would be greatest among the smaller appliances, where even a clear knowledge of device energy would be unlikely to sway appliance selection founded on other more salient characteristics.

4.1.2. The 'principal-agent' problem

Discussion thus far implicitly assumed that both benefits and costs of any appliance purchase will flow to the purchaser. Particularly in the case of the larger 'thermal' appliances that is not always so. Appliances such as hot water systems for example may be bought by owners of rental accommodation, or by property developers completing dwellings for sale. In such cases while the purchaser will bear any additional cost incurred through the selection of higher efficiency appliances, they will not experience the subsequent benefits of reduced energy consumption. This may lead to the broader economic 'principal-agent' problem, a situation where one entity (the 'agent') acts on behalf of another (the 'principal') but acts in a manner contrary to the principal's interests [25]. It is often difficult for the future value of such savings to be embedded in either dwelling purchase cost, or rental. Even where a premium to take such savings into account has been incorporated in rental, for example, it has been shown that tenants may act in a manner as to increase their energy consumption by an amount greater than the premium [26].

4.2. Incentives

Fiscal incentives may be positive or negative, in either making preferred goods and services cheaper, or others more expensive where a reduction in their consumption is sought. A widely used positive incentive has been that used to subsidise renewable electricity development in various countries. It is exemplified by the German Feed-in Tariff (FIT), a measure requiring the purchase of renewable energy by distributors at specified (and hence to generators, guaranteed) prices [27]. A negative incentive may be seen in the UK fiscal measure which re-fashioned the annual road tax for cars in that country to make it dependent on the level of vehicle emissions [28].

Negative incentives in the form of taxes on domestic electricity may impact on the larger appliances, but, as outlined above, are unlikely to affect smaller appliances. Taxes specifically targeted at domestic energy are also likely to be problematic politically. Positive incentives through subsidies are hence more common, but may suffer from a 'free rider' problem. This occurs where incentives are paid to those who would have bought efficient appliances in any case, thus increasing the cost to government of the incentive system [24]. In one notable study in Norway, assessment of incentives for participation in an energy conservation program indicated that around 70% of those taking up the incentive would have undertaken the investment within two

years in any case, without the incentive [29]. While careful policy design may seek to minimise the impact of free riders, it may in practice be very difficult to identify *ex ante* the likely takeup of an energy efficiency measure in the absence of a subsidy incentive.

4.3. Regulation

Pure regulation has not been common in emission reduction measures. Where it has been used it has been both positively and negatively directed. Negative regulation for example may be seen in the mandatory phasing out of incandescent light bulbs by the EU and Australia from 2008 forward [30,31]. Positive regulation may be typified by Australia's mandatory Renewable Energy Target (RET), requiring the purchase by electricity retailers of a certain quantity of renewable energy [32]. Regulation may also be deployed as the setting of standards of performance, an increasingly important policy tool discussed further below.

4.4. Voluntary agreements

Voluntary agreements (VAs) for emission reductions have seen wide use. Japan's emission reduction measures for example are heavily reliant on the VA undertaken between the government and industry sectors through Keidanren, the Japanese industry organisation [33]. Single sector VAs have also been used, as for example with steel plants in China, and industry sectors in The Netherlands [34]. While VAs offer fewer difficulties in their introduction than do more coercive measures, questions have been raised as to their real effectiveness. From a survey of actual national programs the OECD [35] concluded, in regard to VAs generally, that "the effectiveness of voluntary approaches is still questionable". VAs are arguably the second least coercive of the instruments available to government, (information provision being the least) although noted as often existing "under a shadow of regulation" [36].

Voluntary agreements are however not widely used in the appliance efficiency field. The International Energy Agency's (IEA) database on policies and measures shows only several examples, impacting on issues such as incandescent light bulb phaseout in France, and standby power consumption reduction in Japan [37]. Both these are issues addressed by regulation elsewhere. Voluntary agreements may play a role in the development of performance standards under regulation—but here it is regulation which is the operational instrument and provides the principal driver for efficiency improvement.

4.5. Tradeable permit/emissions trading systems

Market based emissions trading systems (ETS) function to facilitate the reduction of emissions at lowest cost, and operate at various jurisdictional levels. The Regional Greenhouse Gas Initiative among ten US states for example is a cap-and-trade system which undertook its first permit auction in 2008 [38]. Nationally, New Zealand proclaimed its domestic ETS in 2008 with the major energy sectors being included from 2010 [39]. At the supranational level the European ETS has been the 'flagship' trading scheme since its inception in 2005 [40]. All such systems function on the basis of mandating a cap on emissions (a regulatory step), with participants in the market having the alternatives of buying emission credits to cover their excess emissions, reducing their emissions below their assigned limits and selling the resultant credits, or simply trading.

A related form of tradeable permit/certificate system has relevance to certain appliances whose greenhouse gas emission reductions may be adequate to justify a permit system. For example the Australian Small-scale Renewable Energy Scheme is designed to induce the purchase of solar or air-source hot water systems through a tradeable certificate (certified emission reduction) system. In most cases in that scheme however the associated certificates are routinely taken into account by the equipment supplier [32], thereby appearing to the purchaser simply as a discount or purchase subsidy. That reflects the fact that as the amount of energy saving which individuals might be able to trade is generally only modest, transaction costs for individual participation in such trading schemes are virtually prohibitive.

4.5.1. Emissions trading systems and a carbon price

A consequence of implementing a broadly based emissions trading system across an economy is that a price is implicitly attached to any unit of carbon which contributes to GHG emissions, with that price flowing through the economy to services such as electricity. The ETS thereby generates an incentive across the economy to reduce the consumption of energy services. In principle, and with appropriate design, such a system should render unnecessary any other policy instrument for this purpose. As the Australian Government's review of its Climate Change programs (the 'Wilkins Review') put it "[i]f there were a broad-based perfectly functioning emissions trading scheme in Australia, there would be no need for any complementary policies." [41]. That review however recognised the need for a range of complementary measures, and focused on means of ensuring that policies were truly complementary.

The International Energy Agency reached a similar view. Taking as its starting point that energy efficiency should be at the core of the policy response to GHG emissions, it concluded that "..while carbon pricing is a prerequisite for least-cost carbon mitigation strategies, carbon pricing is not enough to overcome all the barriers to cost effective energy efficiency actions." [42]. Those barriers included imperfect information, principal-agent problems, and behavioural failures, the latter being largely through the presence of bounded rationality ('rationality' in the definitional sense noted in Section 4.1). Gillingham et al. [43] noted also the possibility of decision-making influences from prospect theory (where consumers value asymmetrically gains or losses of similar magnitude, potentially leading to conservatism in decisions) and the use of heuristics (various strategies adopted to simplify the cognitive task of decision making, even if at the cost of utility maximisation). Tversky's EBA model [23] noted in Section 4.1.2 would be an example of such an heuristic.

The discussion which follows proceeds on the basis that a simple ETS alone can not adequately address the available avenues for energy efficiency improvement in the appliance field and considers the instruments which might be used for that purpose.

5. Appliance instruments in use

Of the five instruments considered above two (voluntary agreements, and permit trading systems) are not considered of major value at the individual consumer level where purchase decisions on efficient appliances are made. The sections following consider the remaining three types (information provision, regulation and incentives) with several examples of each. For a wider range of example programs, and more detailed information, the IEA database *Energy Efficiency—Policies and Measures* [37] provides a valuable overview of international programs and instrument use.

5.1. Information systems (labeling)

Labeling systems are used for three distinct purposes—to indicate compliance with a set minimum performance standard,

to provide comparative performance data with the objective of encouraging purchasers to favour more energy efficient models, or to indicate a product of superior performance. One of the best known of the first type is the "CE mark"—an EU standard symbol indicating that the appliance has complied with relevant EU standards and hence may be placed on the market and move freely within the EU [44]. Such systems focus on compliance rather than relative performance, and hence are essentially adjuncts of minimum performance standard systems.

The second type of label seeks to address market failure arising through 'bounded rationality', as noted in Section 4.1, which suggests that "[h]umans…must make inferences about unknown features of their world under constraints of limited time, knowledge, and computational capacities" [45]. Decisions are influenced by limited information, the purchaser's own capabilities and, as Goto et al. [46] put it, the "cost of thinking". Label programs seeking to enhance a potential purchaser's knowledge rely on an assumption of rationality—that presented with all relevant information, an individual will make choices which maximise personal benefit.

Such labels may as a minimum seek to address an information deficiency concerning a product's characteristics, or go further and provide some partly processed information (for example, the annual cost of operation) to simplify the purchaser's decision-making task. The Australian Energy Rating Label is an example of the former type, quoting for most appliances the electricity consumed per year in typical use [47]. The US EnergyGuide label is of the latter type, presenting the cost per year for typical use cycles and a standard electricity cost, in addition to basic electricity consumption [48].

The third type of label seeks to impart some 'premium' value to an appliance by recognising superior performance. The German 'Blue Angel' environmental labeling system awarded in 2009 its first energy efficiency-based labels for products such as netbooks and electric kettles. The Blue Angel, founded in 1978, sees itself as "an ecological beacon showing the consumer the way to the ecologically superior product" [49]. The US 'Energy Star' label system has a similar objective. It commenced in 1992 and coverage now extends beyond appliances, to new homes and commercial buildings, and the broad provision of advice and assistance on energy saving [50]. Similar systems operate in other countries, all sharing a common feature of identifying appliances of superior energy performance—and hence also targeting the 'bounded rationality' issue.

Labeling systems providing information still leave the purchasing decision with the consumer. Another approach however limits consumer choice by precluding low-efficiency products—through the application of minimum energy performance standards (MEPS).

5.2. Regulation: Minimum energy performance standards

The concept of MEPS is essentially simple—to legally enforce performance standards on either an individual appliance or class basis. In practice however, as with other policy instruments, it is the specific implementation details which determine the real impact of the measure. Minimum performance standards vary in their application in a number of ways through

- the intended effect of the standard
- the manner in which the standard is determined
- the method of measuring compliance and
- the time frame allowed for compliance.

The objective of MEPS systems is to reduce overall energy consumption in the delivery of the desired service from the appliance concerned. If it is assumed that in most situations prior to the application of MEPS appliance efficiencies will vary over a range, then a reduction in overall consumption may be done in various ways by

- simply removing from sale the least efficient devices
- seeking to improve the efficiency throughout the range generally or
- pursuing the development of more efficient devices, with a specific focus on fostering development of new products of higher efficiency than those currently in the market.

Each objective implies setting standards at different levels, and indeed may be applied consecutively. For example initial standards may be set so as to exclude from sale the least efficient current appliances, with subsequent standard development seeking to raise class efficiency over the range. In the first instance no product development is required to achieve an improved average efficiency; in the latter product development and innovation is required.

Performance standards may also be determined based on broader practical and policy considerations. Examples from the EU, US, and Japan illustrate the range of approaches adopted. Arguably the most explicit measure in setting out its objective is the EU Directive 2009/125/EC [44], governing the minimum standards which individual appliances must meet to be eligible for sale in the EU. Annex II of the directive specifies that "the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects", in a process using realistic product lifetimes, and discount rates from the European Central Bank. Technical options for improvement must be identified through technical, environmental and economic analysis, taking account of economic viability and any significant performance loss. The analysis must include also an assessment of the best performing products and technology, and both product performance and benchmarks from other national systems.

The US approach to standard setting is similar, while addressing a broader range of factors. In an iterative process stakeholder views are sought, analysis (market, engineering and cost–benefit) undertaken, further consultation sought on preliminary results, and analyses repeated where necessary. Factors statutorily required to be taken into account include, for any proposed standard, economic impacts, energy savings, any performance reduction, competition effects, and any other factors deemed relevant. In addition, the standard setting process must result in levels which achieve the maximum improvement in energy efficiency which is technically possible and economically justified [51].

Taking a different approach, the 'Top Runner' system adopted in Japan focuses more on demonstrated existing performance, with the identified 'Top Runner' products effectively setting a future benchmark for others. In principle, the Top Runner concept implies that "energy conservation standards for electric appliances, etc. shall be set exactly the same as or higher than the best standard value of each product item currently available in the market" [52]. Thus as appliance designs evolve, the Top Runner approach provides an implicit driver to continually raise the level of performance in the product class overall. In practice, while best current performance forms the basis of evaluation, allowance is also made for expected technological development, in extensive consultation with manufacturers and other stakeholders [53]. Published target years give manufacturers clarity as to required compliance. When measured, compliance is measured by manufacturer's product class weighted average, against the set Top Runner standard [54]. Mechanisms (largely 'name and shame'

approaches) exist to impose sanctions on manufacturers who do not meet specified requirements [53].

A standard feature of the determination of MEPS levels has been the assessment of economic impacts. Examples may be seen from the US [68], the EU [69] and Australia [70]—all regulatory impact assessment statements or their functional equivalents. Such measures help to ensure that the use of regulation does not impose negative impacts in its pursuit of environmental effectiveness—a necessary factor if the potential disadvantage of regulation in the form of MEPS is to be avoided.

5.3. Incentives—Fiscal and subsidy instruments

Labeling systems seek to encourage consumer decisions in favour of energy efficient purchases by capitalising either on consumers' economic rationality (in showing the economic benefit to consumers of energy efficiency) or consumers' preparedness to contribute to the common good (by demonstrating the environmental advantage of their purchase). Minimum energy performance requirements on the other hand essentially preempt consumer preference, by limiting consumer choice to products of a certain minimum performance level. The third major approach relies on modifying the price set within which consumers make decisions, to make more attractive the purchase of the higher energy efficiency products. These incentives may be generated in a variety of ways including direct payments to purchasers, and tax credits or rebates.

A variety of mechanisms of differing detail may be used to deliver an incentive to purchase. Comparisons between these are not discussed here, as the objective is to consider differences between broad classes of policy instruments. The use of subsidies to pursue energy efficiency however has been relatively widespread. The World Energy Council, considering 78 countries, separately lists incentives provided for appliances, lamps and water heating. Table 2 shows the number of countries in which incentives have been provided [55].

While significant, the number of countries using incentives is still much lower than those employing minimum performance standards for major appliances. The same WEC database for example shows 63 countries using MEPS for refrigerators, 56 for washing machines, and 40 for air conditioners [55].

In addition to those listed, other measures have been put in place as a result of the 2007 global economic crisis. Governments deployed energy efficiency funding as part of explicit stimulus measures in Italy for example [37] and in the US through funding from the American Recovery and Reinvestment Act of 2009 [56]. These will not be further considered here, as the reasons for their deployment are only secondarily those of energy efficiency. However they do serve to demonstrate recognition that such expenditures may be closely targeted, and relatively effective and rapid in their response.

6. Ranking policy instruments for appliance energy

The practical set of policy instruments available and in use to address the significant energy use (and hence emissions) associated with appliances comprises

Table 2
Number of countries offering incentives in different classes.

	Appliances	Lamps	Water heaters
Subsidy	11	15	22
Tax benefits	4	5	5

Data from [55].

- information provision
- incentives in the form of subsidies of various types and
- regulation in the form of product performance requirements (MEPS).

Various criteria have been used to evaluate and rank the different types of instruments. One such set suggested by the OECD [57] includes

- environmental effectiveness
- economic efficiency
- impact on competitiveness
- feasibility of implementation
- stimulation of long-term technological innovation and
- any "softer" measures of success, such as increased awareness or engagement generated by use of the instrument.

Of these factors, those most relevant to the instruments and objective considered here are environmental effectiveness, economic efficiency, and, related to that, stimulation of innovation. Other factors listed, while important, are much less likely to provide major points of difference between the three instrument types discussed.

Environmental effectiveness: information programs help promote energy efficiency but as discussed in Section 4.1 their effectiveness in influencing purchase decisions is questionable. Subsidies are more likely to induce the uptake of efficient appliances, although their effect is less predictable than that of regulation. MEPS, enacted in law, would be expected to be the instrument most capable of producing high and predictable increases in appliance efficiency—subject to adequate compliance monitoring.

Economic efficiency – achieving the desired outcome at the lowest possible cost – is determined by both cost and goal achievement. Information programs, while low in total cost, are also lower than subsidies and regulation in their achievement of environmental effectiveness. They are likely overall to be less economically efficient than the alternatives, for an equivalent level of effectiveness. Of those alternatives, subsidy programs can be handicapped by the presence of free riders. Subsidies to free-riders do not induce action—hence their cost reduces the economic efficiency of the overall measure. In addition, subsidy provision appears most prevalent in devices of high energy usage such as water heaters [55]—applications where the greatest likelihood exists for a positive economic case even without subsidies. The cost of regulation may be relatively low for government, but may be significant for firms' compliance—and hence for consumers, firms being assumed here to be able to pass on their costs to those consumers. Compliance cost is strongly affected by the efficiency level demanded, and the extent to which that raises appliance prices. That in turn is influenced by whether redesign and innovation may be used to achieve lower product cost, a centrally important issue. It is innovation and resulting technological change which may be harnessed to pursue higher energy efficiency, at constant or possibly lower product cost.

Pickman [58], citing US manufacturing data, noted that innovation was an industry response to environmental regulation, albeit it might entail substitution from other alternative innovation avenues. From a broad survey of the empirical literature on environmental policy and technological change Vollebergh [59] similarly concluded that environmental policy initiatives had an impact on at least the direction of technological change, regardless of the type of instrument used. He noted that particularly in the process emissions field, standards served to provide clear signals as to what attributes of processes were undesirable (and by inference, what were desirable). As he put it "[s]tandard-driven technological

change is directed by the physical signal given by the standard". In terms of appliances, energy efficiency as such is not a normal design criterion for manufacturers [60], in the absence of Vollebergh's 'signal'. Where that signal is given (and that is most clearly through the definition of performance standards) innovation may work to offset the costs potentially arising from that increased efficiency.

The phenomenon of appliance prices dropping after performance-improving regulation was introduced has been noted in a number of cases. Greening et al. [61] assessed the case of refrigerator/freezer price movements in the US after performance standards were introduced in 1990 and 1993. They concluded that the higher efficiency of new models did not lead to an increase in 'quality-adjusted' prices, which had indeed continued to decrease in line with historical trends. Dale et al. [65] identified similar results over a range of products, attributing the improvements in price to factors including product innovation, reduced markups, and economies of scale in the production of higher-efficiency units. In the UK, introduction of performance standards (again of refrigerator/freezers) in 1999 occurred at the same time as a significant drop in product prices, attributed in part to increased competition among wholesalers [60]. Using an experience curve approach on three 'wet' appliances, Weiss et al. [62] identified "a robust long-term decline in both specific price and specific energy consumption of large appliances". Clearly price movements resulting from mandated efficiency increases will depend on the circumstances of individual cases. As a minimum, however, it can be said that higher prices do not automatically follow from higher efficiency performance; and more, that innovation, among other factors, offers the potential for real cost reduction.

A notable area in which a performance standard has been promoted as a policy instrument internationally is that of standby power, discussed in Section 2. The International Energy Agency has coordinated an approach premised on a target of one watt standby power for all devices, and a number of countries have commenced regulatory steps in that regard [63]. Standby power is an area of significant potential and one for which the approach of performance standards is well suited and indeed the likely most practical solution.

6.1. Preferred alternatives

The preceding discussion suggests there is a valid and justifiable role for regulation (through minimum energy performance standards) in increasing the efficiency of appliances, and reducing emissions caused by their use. There are arguments however against regulation—some ideological, and others practical. Stavins [64] for example pointed out that regulation in the form of standards may not provide the incentive for ongoing improvement that is found in, for example, taxes. That suggests that regulation should not be used where alternatives of similar efficacy are available, and also that where used, care should be taken to minimise any disadvantage of regulation.

In Section 2 above it was noted that the appliance family fell reasonably naturally into two components—one group, few in number and of significant individual energy consumption, and the other a much larger group with individually smaller consumption levels. The former group offers the possibility of some economic rationale in the choice of energy efficient appliances; the latter group in most cases does not. This division forms a logical basis to determine the use of regulation, with the latter being the appropriate group for which regulation (performance standards) should be the principal instrument to drive change. In the former group, the existence of some economic benefit should be used as the basis to promote change—suggesting a role for labeling and information dissemination, with incentives only being used where there is inadequate economic incentive without subsidy.

At the same time however, where regulatory assessment measures indicate no consumer disadvantage, it is reasonable that MEPS be used to ensure minimum performance for the environmental gains which that ensures, while retaining consumer choice among the complying appliances. As noted in Section 5.3 above, that approach has been adopted with larger appliances in many countries to date.

As a second issue, it is argued here also that where regulation is used, it should be regulation of a dynamic nature to provide the ongoing incentive for improvement claimed for tax-based instruments. The nearest such measure in current practice is the Japanese Top Runner approach [52], premised on two major bases—the adoption of current best performance as the criterion for the future, and a visible and predictable process of standard raising over time. In addition, its use of a class average approach to compliance allows the retention of lower efficiency appliances, providing their performance is compensated by other products. That in turn minimises disadvantage to those consumers for whom higher efficiency devices cannot be justified—for example, those intended for extremely intermittent use.

The role of labeling and information provision clearly differs between the two groups noted above. Where there is material economic benefit to consumers in large appliances of higher efficiency, the role of labeling should be to identify such advantage and promote it to consumers. As a second role, 'premium' labeling systems such as the Blue Angel system should continue to identify superior products to promote their use. For those appliances of lower energy consumption, the role of labeling is primarily to confirm compliance with standards—although there is value in labeling systems demonstrating the benefits of standards, to promote public support for such systems. That in turn may make the political task of standard setting more broadly feasible.

A final issue in terms of choice between the three policy instruments considered here lies in the potential for regulatory measures to address matters not able to be addressed by other means— as for example where more than one aspect of performance needs be addressed. This is illustrated by the case of standby power consumption, that potentially substantial energy use which goes on when the appliance concerned is not delivering its service. The problem which arises in addressing this consumption is that there is not necessarily a correlation between overall appliance efficiency, and the level of standby power. Hence performance-based labels which are based on one variable only may give entirely the wrong signal to consumers in terms of another variable. Regulation however, providing it is consistent, can separately address the two variables in parallel—a useful feature when more than one appliance characteristic is of importance.

7. Conclusions

The analysis above reveals three main issues most relevant to appliance efficiency arising from the application of the three instruments information provision, incentives and regulation:

- the nature of the two groups into which appliances generally fall, and the effect of that on instrument suitability
- the multiple roles played by two of the instruments and
- the relative importance of the instruments as drivers for change, and any conditions on their use

The two groups of appliances included a set of only three larger appliances of significant energy consumption—space

heating and cooling systems, water heating systems, and perhaps refrigerator/freezers, and a numerically far larger set of devices each of far lower unit energy consumption than the first set. Because of both their higher energy consumption, and also their higher cost, those of the first set are more likely to receive in-depth assessment in their purchase—with that assessment likely to include the magnitude of energy use as a variable. For that reason, the first set of appliances offers a greater possibility for higher energy efficiency to be a positive influence in the purchase decision. In turn that suggests that information provision through labeling and other means may be of value, and also that subsidies carefully designed to produce the minimum necessary economic case for purchase may be effective. Because of the gains to be made from improving the energy consumption of this group, performance standards are also commonly used, because of their effectiveness, to exclude low-efficiency appliances.

The second group of appliances appears likely to be little affected by subsidies (given a low energy component of total cost), and also to be little affected directly by labeling programs, in the presence of competing performance parameters influencing consumer choice. Achieving efficiency improvement in this group must largely rely on regulation in the form of performance standards to address the supply side, rather than the demand side of the market. Where performance standards for the first set simply define a base level, those for the second set effectively are the principal motivators for improvement.

Regulation in this manner plays a different role with the two groups of appliances—defining a minimum acceptable performance in one, and in the other likely to be the principal determinant of outcomes. A second instrument – information provision – also has multiple functions. In the case of the first set of appliances, the role of information provision is to the extent possible to influence consumers' actions by informing them of potential gains. While there is an element of persuasion in influencing attitudes, it is the informational role which is most relevant. With the second set of appliances, the role of information provision is to identify the necessary compliance with defined standards—but also to aid acceptance of those standards by identifying the gains to be made through efficiency improvement. It is regulation in this case which provides the necessary driver for improvement.

That in turn suggests that with appliances overall, regulation in the form of minimum performance standards has a perhaps surprisingly high influence—in the determination of performance in the smaller appliance group, and in setting a baseline for larger appliances. It has been argued here that to effectively utilise regulation in both these functions, the regulation process itself should be dynamic, employing progressive enhancement of standards of the type demonstrated by, for example, the Japanese Top Runner system. That process would involve continuing and transparent standards development based on demonstrated performance, and be applied on a class compliance basis to preserve maximum choice for consumers, in the context of overall increases in appliance class efficiency. Undertaken in this manner, regulation of appliance performance has a significant role to play in the reduction of domestic energy consumption.

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